THE UNVERIFIABLE HYPOTHESES OF SCIENCE.

MORE and more the conviction grows and spreads, that science is or is to be the light of the world. The one supreme gift of education is or is to be the scientific attitude of mind. The problem of problems, therefore, is to understand, to make lucid, to make conscious, to make transmissible the essentials of scientific thinking.

The bond of harmonious world-life is the scientific habit of mind. How horribly we have been hypnotized by words and out-worn creeds, while even yet eighty percent of us die from causes completely preventable.

The marvelous objective contributions of science flare up on every hand about us. The chemist's coal-tar colors are not more vivid than the lurid light of electricity, now a household fairy with telephone and electric smoothing iron. While the X-rays reveal our very bones and wireless telegraphy pierces the blackest of ocean's tempests, we are unastonished while Sir William Ramsay and Madame Curie debate whether the dream of the alchemists, the transmutation of metals, has come true.

But these gemmed palaces uprising at the rubbing of the Aladdin's lamp of science, looked at only from without, unmastered, lend themselves only too readily to the aid of the false magician, dealer in the magic of words.

Calling Christ scientist was the shrewd appropriation and utilization by Mrs. Eddy of the universally growing conviction of even the densely unscientific that science is the hope of the world. Willingness to try the swallowing

of a cholagogue with so sympathetic a trade mark was actually stimulated by the real wonder-working of true science. Men and women can be charmed with words. Things, much more stubborn, bow only to the sovereignty of one kind of thought, the scientific. What then are the identifying characteristics of this the only lawful prince?

For example, wherein differ these three beliefs, the belief of the Coreans that epileptic fits are demoniacal seizures to be treated by trying to cast out the devils, the Mrs. Eddy contention that there is no sickness and the epileptic fits are only illusions caused by malicious animal magnetism, a suppositious entity relief from which she has actually sought in our law courts, and finally the position of the Japanese army-surgeons that an epileptic fit is a phenomenon produced by an abnormal explosive discharge of nerve force overflowing proper channels, self-limited as the flood from a bursting water tank, not stopped by the exorcising of a demon? An epileptic seizure is often preceded and heralded by a distinctly recognizable aura. Is the one who feels the oncoming stroke, to pray, to telephone for the police, or instantly to snuff up the nose the fumes from an uncorked bottle of nitrite of amyl?

From nothing assumed, nothing can be proved! Every conclusion supposes premises. But even the learned have heretofore not realized that the necessary hypotheses of science are of two distinct kinds. Every one has recognized those hypotheses which are valuable *precisely* because they are either verifiable or else refutable through definite appeal to the tests furnished by what we have called experience and experiment. However, what we call experience and experiment is not all. No scientist has ever been able to get on without hypotheses. But the essential thing is never to make them unconsciously, and the scientist of the past has here been a sinner.

The epoch-making revelation is that among the scien-

tist's necessary assumptions, both conscious and unconscious, are some of a kind hitherto unrecognized, of a genus wholly different from what he thought them, hypotheses wholly and forever indemonstrable, which experience and experiment, however interpreted, are eternally inadequate to prove. Once pointed out, the antithesis, the contrast between these two species of scientific hypotheses is strikingly abrupt. The routine scientist, taken unawares, would be tempted stoutly to deny the scientific importance, yea, the very existence in science, of hypotheses of this newly revealed type. What! a scientific hypothesis by its very nature incapable of proof! Far be it from him! Yet to these unrecognized friends he has owed, he owes all his success. From their stimulus, with their guidance under their protecting wings he has done all his work toward interpreting his experiments, his experience, his world.

Such a hypothesis, yet so long misunderstood, is Euclid's celebrated parallel postulate, familiar in Ludlam's form: Two straight lines which cut one another cannot be both parallel to the same straight line.

How easy this hypothesis! Why not prove it? Almost every man of science throughout the ages did try to prove it. Says Poincaré: "What vast effort has been wasted in this chimeric hope is truly unimaginable."

At last comes the new step. Says Lobatchevsky: "In the uncertainty whether through a point there is only one straight coplanar with a given straight yet nowhere meeting it, we will assume it may be possible that there are still other straights which do not cut the given straight, though coplanar with it and through the given point."

Here then we have Euclid's hypothesis characterized as a scientific assumption forever indemonstrable and therefore subject to direct, explicit contradiction, subject to replacement by an assumption flatly contradicting it.

Bolyai speaks just as explicitly of the system of geometry resting upon Euclid's hypothesis, and the system founded on the contrary hypothesis, that there are coplanar straights not both perpendicular to any third, yet which nowhere meet, straights which are asymptotes each to the other. And this Bolyai geometry is of a logic nowise inferior to the Euclidean.

Is, then, the Euclidean geometry true? This question, says Poincaré, has no meaning. As well ask whether Cartesian coordinates are true and polar coordinates false. But says Professor Roe, the sun will rise to-morrow and must rise in time and space.

Too late, my dear Professor, too late. Since the hypothesis of Copernicus, the sun does not rise, the earth rotates. Since the hypothesis of Bolyai, if it rose in geometric space it might be Lobatchevsky's, but it does not rise in a geometric or conceptual space. Such space is one, empty, homogeneous, continuous, unbounded, perhaps infinite, infinitely divisible, identical, invariable. But the where of physical motion, if we still insist upon calling it some kind of space, is perceptual space, hence multiple, filled, heterogeneous, perhaps continuous only for perception, perhaps finite, not infinitely divisible, variable. Our physical world is neither in Euclidean nor non-Euclidean space, for these are conceptual constructs. Geometric space is a construction by the intellect, made by methods entirely analogous to the ordinary ways in which we achieve our selfish purposes, and call the achievement truth.

The certainty of the science of geometry is only the certainty of deduction from hypotheses, and because of the final necessity of unverifiable hypotheses, we must now have some criterion other than proof. Here is one: Of alternative hypotheses is to be chosen the simplest now for us.

Man is the measure of all things. The debate, what

is truth? is a wrangle unless it gives precedence to the kenlore question, How can *reality* like a new planet swim into my ken? Then we find our knowing is ever subject to our wishing. As Schiller says: "At a blow it awards to the ethical conception of *Good* supreme authority over the logical conception of *True* and the metaphysical conception of *Real.* The Good becomes a determinant both of the True and of the Real. Our apprehension of the *Real,* our comprehension of the *True,* is always effected by beings who are aiming at the attainment of some *Good,* and it seems a palpable absurdity to deny that this fact makes a stupendous difference." That is clung to as real which has entangled itself in our emotional life. Could you induce a dear old lady to give up her conviction of the importance of circumcision and the devil? And I agree with her as to one and beg to differ as to the other.

How well I remember that when it was my privilege to study astronomy with Newcomb he showed that the Ptolemaic hypothesis was perfectly adequate for the calculation of eclipses, only too cumbersome as compared to the Copernican, while on the contrary the three Kepler laws offer no definite or complete solution of the problem of the movements of the heavenly bodies, their importance being that of the fabled apple, they hit the tremendous head of Newton.

John Bolyai it was who in 1823 first wrote down that quality of an infinite aggregate which in these latter days of tardy appreciation we have adopted as its definition: "An infinite aggregate is one equivalent to a part of itself."

You know the algebraic paradox that two equals one, an excellent way of justifying our convention that you must not divide by zero; but though only every other integer is even, yet for every number there is an even number,—the whole is not greater than its part—for every point on a yard there is a point on a foot.

The hypothesis of the uniformity of nature is unverifiable. Here it is: Reproduce all the conditions of a certain phenomenon, that phenomenon will reappear. Of this Dr. Carus has lately said: "It would be useless even as a working hypothesis; for, as Mrs. Warren truly explains, we can never reproduce the very same conditions a second time."

But Royce of Harvard, in his introduction to my translation of Poincaré's *Science and Hypothesis*, says of what, to fix the ideas, I here call okapi hypotheses:

"These are far less frequently recognized in a perfectly explicit way as useful aids in the work of special science. One usually either fails to admit their presence in scientific work, or else remains silent as to the reasons of their usefulness. Our author's treatment of the work of science is therefore especially marked by the fact that he explicitly makes prominent both the existence and the scientific importance of hypotheses of this second type. These hypotheses which can neither be confirmed nor refuted by experience appear partly (like the conception of 'continuous quantity') as devices of the understanding whereby we give conceptual unity and an invisible connectedness to certain types of phenomenal facts which come to us in discrete form and in a confused variety; and partly (like the larger organizing concepts of science) as principles regarding the structure of the world in its wholeness; *i. e.,* as principles in the light of which we try to interpret our experience, so as to give to it a totality and an inclusive unity such as Euclidean space, or such as the world of the theory of energy is conceived to possess. Those aspects of science which are determined by the use of the hypotheses of this second kind appear in our author's account as constituting an essential human way of viewing nature, an interpretation rather than a portrayal or a prediction of the objective facts of nature, an adjustment of our conceptions of things to the internal needs of our intelligence.

Unverifiable and irrefutable hypotheses in science are indeed, in general indispensable aids to the organization and to the guidance of our interpretation of experience. Characteristic remains the thought that *without principles which at every stage transcend precise confirmation through such experience as is then accessible the organization of experience is impossible.* They may therefore be described as hypotheses that, while lying at the basis of our actual physical sciences, at once refer to experience and help us in dealing with experience, and are yet neither confirmed nor refuted by the experiences which we possess or which we can hope to attain."

Three special instances or classes of instances may be used as illustrations of this general type of hypotheses.

They are: (1) The hypothesis of the existence of continuous extensive *quanta* in nature; (2) The principles of geometry; (3) The principles of mechanics and of the general theory of energy. In the case of each of these special types of hypotheses we are at first disposed, apart from reflection, to say that we *find* the world to be thus or thus, so that, for instance, we can confirm the thesis according to which nature contains continuous magnitudes; or can prove or disprove the physical truth of the postulates of Euclidean geometry; or can confirm by definite experience the objective validity of the principles of mechanics. A closer examination reveals the incorrectness of all such opinions. Hypotheses of these special types are needed; and their usefulness can be empirically shown. They are in touch with experience; and that they are not merely arbitrary conventions is also verifiable. They are not *a priori* necessities; and we can easily conceive intelligent beings whose experience could be best interpreted without using these hypotheses. Yet these hypotheses are *not* subject to direct confirmation or refutation by experience. They stand then in sharp contrast to the scientific hypotheses of

the other, and more frequently recognized, type, *i. e.,* to the hypotheses which *can* be tested by a definite appeal to experience.

The central problem of the logic of science thus becomes the problem of the relation between the two fundamentally distinct types of hypotheses, i. e., between those which cannot be verified or refuted through experience, and those which can be empirically tested.

One value of unverifiable and irrefutable hypotheses of this type lies in the sort of empirical inquiries which they initiate, inspire, organize and guide. In these inquiries hypotheses in the narrower sense, that is, trial propositions which are to be submitted to definite empirical control, are indeed everywhere present. Yet without the "leading ideas" of science, that is, its principles of an unverifiable and irrefutable character, the hypotheses in the narrower sense would lack that guidance which the larger ideas of science give to empirical investigation."

And now from the cavayard of young giraffe and okapi found new-prancing in the fair field of modern dynamic, following here Poincaré's delineation, I shall cut out two for exhibition. *Voilà!*

What characterized the Newtonian mechanics? Simply this: Take a body at rest; give it an impulse, that is, impress on it a given force for a given time; the body starts to move and acquires a certain velocity. The body having this velocity, if we again impress the same force during the same time, the velocity will be doubled. If we still continue, the velocity will be tripled after we shall a third time have given the same impulse. Thus beginning again a sufficient number of times, the body will end by acquiring a very great velocity, which could surpass any limit, an infinite velocity.

In the new mechanics, on the contrary, we suppose it impossible to give to a body starting from rest a velocity

greater than that of light. What happens? Consider the same body at rest; give it the same impulse as before; it takes the same velocity. Repeat again this impulse, the velocity will augment, but it will not be doubled. A third impulse will produce an analogous effect, the velocity augments but less and less; the body opposes a resistance which becomes greater and greater. This resistance is inertia, is what we commonly call mass.

Everything happens, then, in this new mechanics as if the mass was not constant, but increased with velocity.

We may represent the phenomena graphically. In the Newtonian mechanics, the body takes after the first impulse a velocity represented by the sect Ov_1; after the second impulse, Ov_1 increases by a sect v_1v_2 equal to it. At each new impulse, the velocity increases by the same qantity; the sect representing it increases by a constant length. In the new mechanics, the velocity-sect increases by sects $v'_1v'_2$, $v'_2v'_3$,... which are smaller and smaller and such that we cannot exceed a certain limit, the velocity of light.

How have we been led to such a conclusion? Have we made direct experiments? The divergence would show only for bodies at high velocities; then alone the indicated differences would become sensible.

But what is a very high velocity? Is it the speed of an automobile going at the rate of 100 kilometers per hour? On the road we go wild at such speed; but for the present view-point this is a snail's pace. Astronomy serves us better. Mercury, the speediest of the heavenly bodies, also goes about 100 kilometers, not per hour but per second; but still that is not quick enough; such speeds are too slow to reveal the differences we would observe.

I shall not speak of cannon balls. They are faster than automobiles, but much slower than Mercury. But you know we have discovered an artillery whose projectiles are

quicker far: I mean radium, which shoots out energy projectiles, in every direction. The rapidity of the shot is greater far; the initial velocity is about a hundred thousand kilometers per second, one-third the velocity of light. The caliber of the projectiles and their weight are, it is true, less formidable, and we must not count on this artillery to increase the military strength of our armies. Can we experiment on these projectiles? Such experiments have actually been undertaken. Under the influence of an electric charge, of a magnetic field a deviation happens which permits taking account of inertia and measuring it. It has thus been established that mass depends upon velocity, and the following law has been enunciated: The inertia of a body increases with its velocity which remains always less than that of light, 300,000 kilometers per second. In other words, for this non-Newtonian dynamics a constant force acting upon a moving body does not impart equal increments of velocity, equal accelerations, in equal times, say in each successive second; but the accelerative effect decreases as the velocity increases, and this has for limit the velocity of light. There can be no motion swifter than that of light, about 186,330 miles per second, a very tiny number, while on the other hand the mass of ever so little a body approaches absolute infinity as the measure of its speed approaches this trivially tiny number. Surely this dwarf and giant annex to the staid old Sir Isaac Newton museum, though masquerading as the outcome of experiment, is as bizarre as the okapi of Sir Harry Johnston, defined in the last of the two splendid new volumes of the *Century Dictionary* as having the upper parts dark purplish brown; forehead and ears reddish; sides of face nearly white; legs buff, the flanks and upper parts marked with horizontal blackish stripes resembling those of a zebra,—certainly a color scheme run mad.

Yet after all, this non-Newtonian mechanics owns an-

other hypothesis not less surprising. A body in motion of translation undergoes a deformation in the line of its displacement; a sphere for example, becomes a species of flattened ellipsoid with the shorter axis parallel to the translation. If such a transformation is not seen every day, this is because it is so minute as to be almost imperceptible. The earth revolving in its orbit deforms itself about one two hundred millionth. To observe such a phenomenon instruments would be needed of precision extreme; but were their precision infinite it would not help, because, carried themselves in the movement, they would undergo the same transformation. We should see nothing. The meter we could use would shorten like the length we measured.

Yet even this has not been accepted as settling the species of this bizarre creature. It is claimed that Michelson has shown it to be not okapi but giraffe by verification, and largely this won him the Nobel prize, forty thousand dollars.

Finally, the notion of constant mass of a body having vanished, having evaporated, what becomes of Newton's law of gravitation?

Motion plays havoc with it, and Lorentz has replaced it by a new law of attraction containing the velocities of the two bodies as parameters.

The greater the velocities, the greater the difference between Newtonian and non-Newtonian.

Now of all the planets Mercury has the greatest velocity, and just Mercury presents an anomaly not yet explained: the motion of its perihelion is more rapid than the motion calculated by Newton's law. The acceleration is about 38″ too great. Now the Lorentz law of gravitation would make the acceleration greater than that given by Newton's law.

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